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Supporting Information for

# Grain Size Variations in the Murray Formation: Stratigraphic Evidence for Changing Depositional Environments in Gale Crater, Mars

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## Additional Supporting Information (Files uploaded separately)



## Introduction

This supporting material includes a description of the ChemCam target nomenclature (Text S1), images of some of the calibration rock standards (Fig. S1), the grain size and $G_{MEAN}$ values of GIMS calibration rock standards (Table S1), and GIMS statistics for each stratigraphic locality in the Murray formation (Table S4). Also included are captions for two spreadsheets; one with the ChemCam LIBS data used in the GIMS analysis (Table S2), and the other for the GIMS results (Table S3).

**Text S1. ChemCam target nomenclature**

ChemCam targets are informally named by the MSL science team. When the target names contain multiple words, the words are connected via underscores. When more than one LIBS analysis is acquired on the same rock target, underscores are used to enumerate each analysis location on the rock (i.e., rock_name_1, rock_name _2). These names are provided to the Planetary Data System for cross referencing ChemCam data and associated images. These names are used to reference the rock targets in this publication.

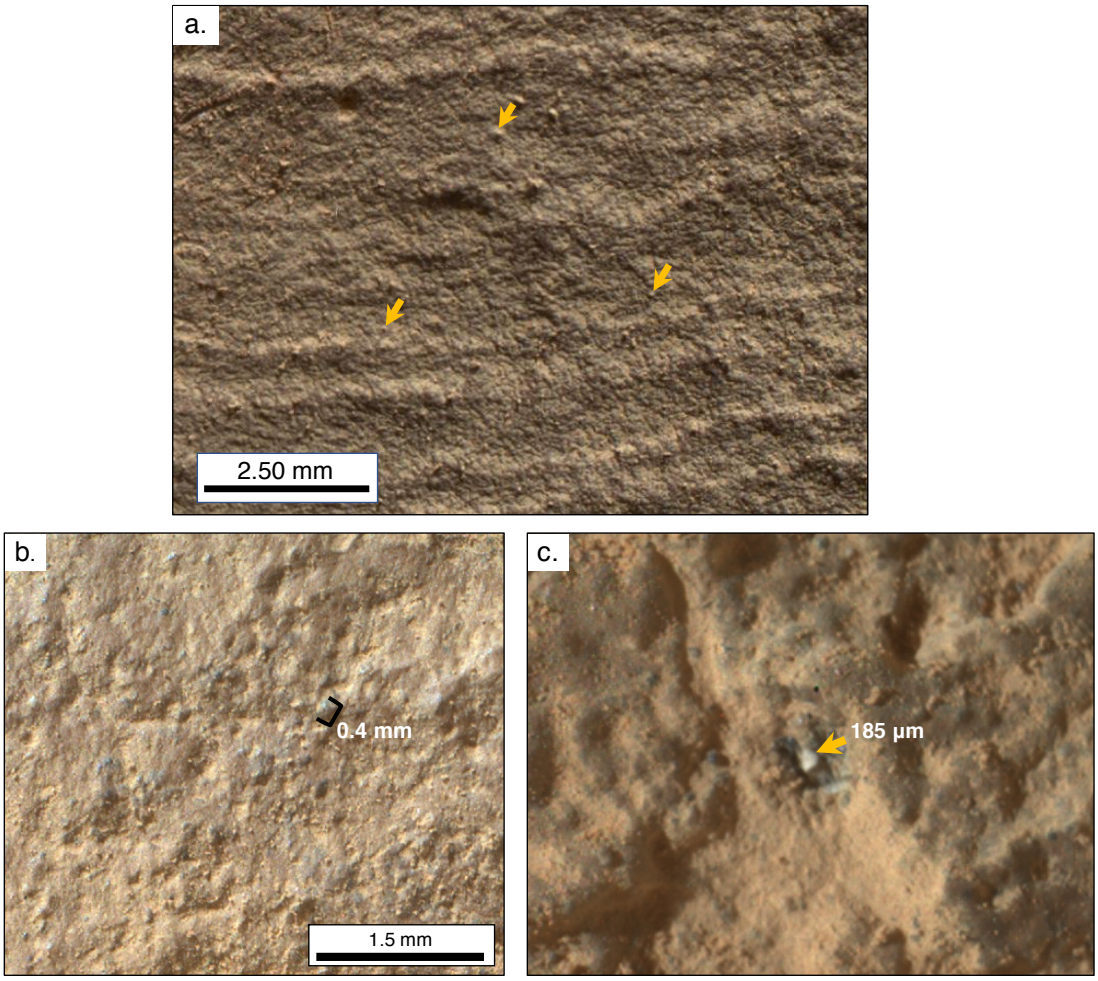


**Figure S1.** Examples of GSR3 (a) and GSR4 (b-c) calibration standards (Table S1). (a) Cropped MAHLI focus merge product showing ChemCam target Conda, taken at ~1 cm standoff on Sol 1436 (1438MH0001530000503527R00). Orange arrows indicate very fine to fine sand sized grains. Note the lamination in Conda. (b) Cropped MAHLI focus merge product of ChemCam target Mason_Point, taken at ~1 cm standoff on Sol 1695 (1695MH0001630000604160R00). The bracket is highlighting a medium sand sized grain. (c) Cropped MAHLI focus merge product of ChemCam target Mitchell_Hill, taken at ~1 cm standoff on Sol 1695 (1695MH0001630000604166R00). The orange arrow indicates a fine sand grain exposed in a ChemCam LIBS pit.

**Table S1.** GIMS calibration rock standards from the Murray formation listed stratigraphically (low to high elevations) by grain size regime. Grain size estimates are based on visible grains at or near the LIBS analyses and surrounding area in MAHLI and RMI images. For rocks at Pahrump Hills, grain size estimates used MAHLI images of regions near the ChemCam analyses (Rivera-Hernandez et al., 2019; Stack et al., 2019). Grain sizes determined from RMI images are marked by asterisks next to the target name. All rock targets have grains that were not resolvable in images and are possibly finer grained. The grain size and $G_{MEAN}$ data are plotted in Figure 3.

| Rock Target Name | Member | Locality interval | Grain size from images | Min and Max $G_{MEAN}$ | Grain Size Regime (GSR) |
|---|---|---|---|---|---|
| The_Maze, Crowley, Hanaupah | Pahrump Hills | Pahrump Hills | Mud to silty/sandy mud, <0.125 mm | 0.04, 0.07 | GSR1 |
| Kudis, Stockdale | Hartmann's Valley | Hartmann's Valley | Coarse silt, < 0.0625 mm | | |
| Goblin_Valley, Deadman_Pass, Aguereberry_Point, Soledad_Pass | Pahrump Hills | Pahrump Hills | Coarse silt to very fine sand, 0.020-0.125 mm | 0.07, 0.10 | GSR2 |
| Inamagando | Hartmann's Valley | Hartmann's Valley | | | |
| Ukuma, Ganda | Karasburg | Murray Buttes | | | |
| Wapiti*, Stenerson* | Pahrump Hills | Marias Pass | Fine to medium sand, 0.125-0.500 mm | 0.11, 0.13 | GSR3 |
| Conda | Karasburg | Murray Buttes | Very fine to fine sand, 0.062-0.250 mm (Figure S1a) | | |
| Orocopia, Vasquez*, Wild Horse Mesa* | Pahrump Hills | Pahrump Hills | Medium to coarse sand, 0.500-1.000 mm | 0.17 0.29 | GSR4 |
| Bobonong* | Sutton Island | Sebina | Medium to vey coarse sand, 0.500-2.000 mm | | |
| Mason_Point | | Newport Ledge | Fine to coarse sand, 0.125-2.000 mm (Figure S1b) | | |
| Mitchell_Hill | | | Fine to medium sand, 0.125-0.500 mm (Figure S1c) | | |
| aegis_post_1685a* | | | Medium to coarse sand, 0.125-2.000 mm | | |

**Table S2.** The ChemCam LIBS data used in the GIMS analysis. The data have already been filtered using the procedure described in *Section 2* and in Rivera-Hernandez et al. (2019**).**

**Table S3.** All targets used in the GIMS analysis with summary information, general grain size estimates from MAHLI and RMI images if known, and $G_{MEAN}$ values with associated standard deviation errors. For targets with N/A grain sizes, grains could not be resolved in any of the images, or images were not available. Protrusions in the rocks that are not grains are likely diagenetic nodules or concretions. Targets with $G_{MEAN}$=0.07 have transitional GSRs, indicated by GSR1/GSR2. Targets names are merged in the same cell for those analyses that were taken on the same rock exposure. Next to the target names,

the symbol * denotes that the ChemCam target was imaged by the MAHLI, the symbol ** denotes that the dust removal tool was used before the MAHLI image was taken, and ~ signifies that a location close to the ChemCam target was imaged by the MAHLI.

**Table S4.** The mean, median, minimum and maximum $G_{MEAN}$ and the minimum and maximum GSR for each locality in the Murray formation.

| Member | Locality interval | # of rock targets | Mean $G_{MEAN}$ | Median $G_{MEAN}$ | STDV $G_{MEAN}$ | min $G_{MEAN}$ | max $G_{MEAN}$ | min GSR | max GSR |
|---|---|---|---|---|---|---|---|---|---|
| Pahrump Hills | Pahrump Hills | 18 | 0.10 | 0.08 | 0.06 | 0.03 | 0.29 | GSR1 | GSR4 |
| | Marias Pass | 7 | 0.14 | 0.12 | 0.09 | 0.04 | 0.32 | GSR1 | GSR4 |
| Hartmann's Valley | Bridger Basin | 5 | 0.11 | 0.11 | 0.04 | 0.05 | 0.17 | GSR1 | GSR4 |
| | Hartmann's Valley | 15 | 0.10 | 0.07 | 0.06 | 0.05 | 0.23 | GSR1 | GSR4 |
| Karasburg | Murray Buttes | 23 | 0.08 | 0.08 | 0.05 | 0.03 | 0.21 | GSR1 | GSR4 |
| Sutton Island | Sebina | 20 | 0.07 | 0.06 | 0.05 | 0.01 | 0.20 | GSR1 | GSR4 |
| | Old Soaker | 26 | 0.06 | 0.06 | 0.03 | 0.02 | 0.11 | GSR1 | GSR3 |
| | Ireson Hill | 22 | 0.04 | 0.04 | 0.02 | 0.01 | 0.07 | GSR1 | GSR1/ GSR2 |
| | Paradise Hill | 23 | 0.04 | 0.03 | 0.01 | 0.01 | 0.07 | GSR1 | GSR2 |
| | Newport Ledge | 15 | 0.12 | 0.12 | 0.07 | 0.02 | 0.30 | GSR1 | GSR4 |
| Blunts Point | Heron Island | 13 | 0.09 | 0.04 | 0.09 | 0.02 | 0.24 | GSR1 | GSR4 |
| | Blunts Point | 22 | 0.03 | 0.03 | 0.03 | 0.00 | 0.06 | GSR1 | GSR1 |